Available online at www.sciencedirect.com

ScienceDirect

Ceramics International 42 (2016) 3000–3006

CERAMICS INTERNATIONAL

www.elsevier.com/locate/ceramint

Effect of silica fume on the mechanical properties of fly ash based-geopolymer concrete

F.N. Okoye[a], J. Durgaprasad[a], N.B. Singh[b,*]

[a]Department of Civil Engineering, Sharda University, Greater Noida, India
[b]Research and Technology Development Centre, Sharda University, Greater Noida, India

Received 22 August 2015; received in revised form 14 October 2015; accepted 15 October 2015
Available online 21 October 2015

Abstract

In this paper fly ash based geopolymer concretes with different percentages of silica fume were made by using NaOH/sodium silicate and cured in an oven at 100 °C. Workability, compressive strength, flexural and tensile strengths were determined. Portland cement concrete was used as a reference. Sodium hydroxide (14 M) and sodium silicate were used as alkali activators. The results have shown that addition of silica fume improved the compressive strength of the produced geopolymer concretes. Tensile and flexural strengths also increased as the silica fume content increased. The geopolymer concretes were found quite durable in the presence of 2% H_2SO_4, 5% Na_2SO_4 and 5% NaCl.

Keywords: Geopolymer; Silica fume; Fly ash; Compressive strength; Flexural strength

1. Introduction

The global use of concrete is second only to water. As the demand for concrete as construction material increases, so also the demand for Portland cement. The cement manufacture is highly energy intensive and each tonne emits about a tonne of CO_2, which is a greenhouse gas causing global warming [1–3]. Thus, there is an urgent need to produce an alternative to cement material with adequate strength and durability in order to make cement industry more eco-friendly and sustainable.

A new binding material known as 'geopolymer' was first introduced by Davidovits in 1978 [4]. The reaction of aluminosilicate materials such as fly ash [5–8], metakaoline [9–12], silica fume [13,14], slag [15,16], rice-husk ash [17], red mud [18], etc. with highly alkaline solutions (hydroxides, silicates) produces geopolymers. Unlike ordinary Portland cement (OPC), geopolymers do not require calcium-silicate-hydrate (C-S-H) gel for matrix formation and strength, but utilise the polycondensation of silica and alumina precursors to achieve the required strength level. In recent years considerable amount of research work on geopolymer cement and concrete is being carried out to elucidate the mechanism of formation, strength development and durability [5]. In our earlier publication we reported the effect of metakaoline on the properties of fly ash based geopolymer concrete [19]. In this paper we have studied the effect of silica fume on the mechanical properties of fly ash based geopolymer concrete.

2. Experimental

2.1. Materials

Low calcium fly ash (Class F) (ASTM C618) was used in this investigation. The fly ash used was obtained from National Power station, Dadri, Uttar Pradesh, India. Silica fume was obtained from Counto microfine products Pvt. Ltd., Pissurlem industrial estate, Pissurlem, Sattari, Goa, India, (BS EN 13263-1 (2005)). OPC-43 was used for making reference concrete. The chemical compositions of OPC, fly ash and silica fume are given in Table 1.

*Corresponding author.
E-mail address: nbsingh43@gmail.com (N.B. Singh).

http://dx.doi.org/10.1016/j.ceramint.2015.10.084

Table 1
Chemical composition of binders.

Constituents	Composition (%)		
	OPC	Fly ash	Silica fume
SiO_2	19.01	50.70	93.67
CaO	66.89	2.38	0.31
MgO	0.81	1.39	0.84
P_2O_5	0.08	–	–
Na_2O	0.09	0.84	0.40
K_2O	1.17	2.40	1.10
MnO	0.19	–	0.84
Al_2O_3	4.68	28.80	0.83
Fe_2O_3	3.20	8.80	1.30
SO_3	3.00	0.30	0.16
Loss of ignition	2.48	3.79	2.10

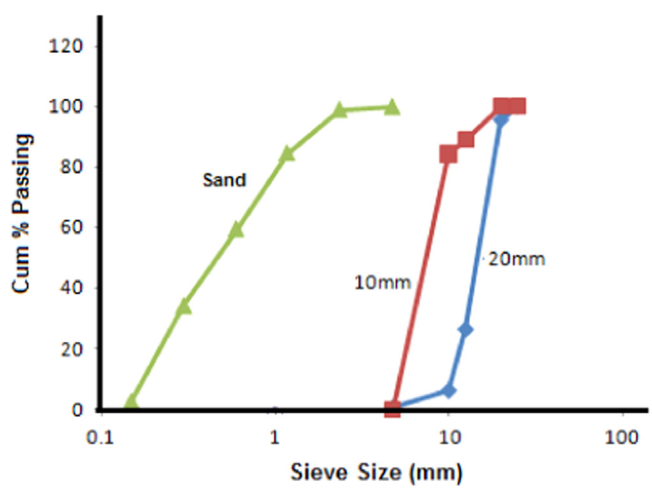

Fig. 1. Grading curve of 20 mm and 10 mm coarse aggregates and sand.

Coarse aggregates of sizes 20 mm and 10 mm were used. Sieve analyses were performed to determine the particle size distribution as prescribed in BS 812, Part1, 1975 while fine aggregate used was river sand and graded as prescribed in BS 812, Part1, 1975 (Fig. 1).

The physical properties of coarse and fine aggregates are given in Table 2.

Sodium hydroxide in the form of pellets with 98% purity and commercially available sodium silicate solution were used. The sodium silicate solution used had a silicon dioxide to sodium oxide ratio (SiO_2/Na_2O) of 2.0 with 60% water by the total weight.

2.2. Preparation of alkali

Solution of sodium hydroxide (14 M) was prepared and left for 24 h before mixing with sodium silicate. The mixture of sodium hydroxide and sodium silicate solutions was left for one day and then used for a geopolymerisation process.

Table 2
Physical properties of gravels and sand.

Sample	Specific gravity	Water absorption (%)	Fineness modulus
20 mm aggregate	2.5	0.17	2.7
10 mm aggregate	2.4	0.87	2.8
Sand	2.6	–	2.1

2.3. Mix proportion of geopolymer concrete

The designs of geopolymer concretes with fly ash were similar to that of OPC concrete. Coarse and fine aggregates were taken as 77% by mass of the entire mixture. The concentration of NaOH solution was 14 M as this concentration gave the highest strength [19]. 1% Naphthalene sulphonate based superplasticiser was used to improve the workability of fresh geopolymer mix. Higher W/S ratio improved the workability but the compressive strength was reduced. So a fixed W/S ratio (0.2) was used in order to have higher compressive strength. The detailed mix design of geopolymer concrete mixes are given in Table 3. Geopolymer mixes with different amount of silica fume (5%, 10%, 15%, 20%, 30% and 40%) were also made. A control mix was cast as M40 with Portland cement concrete to compare the performance of geopolymer concrete.

2.4. Workability test

The workability of the fresh concretes was determined by using slump cone test in compliance with BS EN 12350-2:2000 standard.

2.5. Casting of geopolymer concrete

Casting of geopolymer concrete was done at room temperature in the laboratory in a similar way as described earlier [19]. After mixing, the concrete mixture was cast in a 100 mm × 100mm steel mould in three layers, and each layer was given 60 strokes with 20 mm compacting rod. Six concrete cubes were cast for each mix beside the trial mixes for compressive strength. The split tensile and flexural tests were performed with cylindrical moulds of 150 mm diameter and 300 mm height as per ASTM C 496-90 requirement and beam mould of 100 mm × 100 mm × 500 mm in compliance with EN 12390-51997 requirement respectively.

2.6. Curing and testing of geopolymer specimens

The concrete cubes were demoulded after 48 h and cured in an oven at 100 °C for 72 h since at this temperature, strength was found maximum [19]. The specimens were left at room temperature until the day of testing. The compressive strength of the cubes was determined after 3, 7, 14, 21 and 28 days while the specimens in cylindrical forms for tensile and flexural strengths were left at room temperature for 28 days before testing.